Jun 25th, 4:50 PM - 5:30 PM

Concurrent Sessions C: Multi-Dimensional Modeling and Fish Passage Restoration - Modeling Fish Passage for American Shad in a Steeppass Fishway Using a Computational Fluid Dynamics (CFD) Model

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Modeling Passage for American Shad in a Steeppass Fishway using a CFD Model

Photo Credit: USFWS

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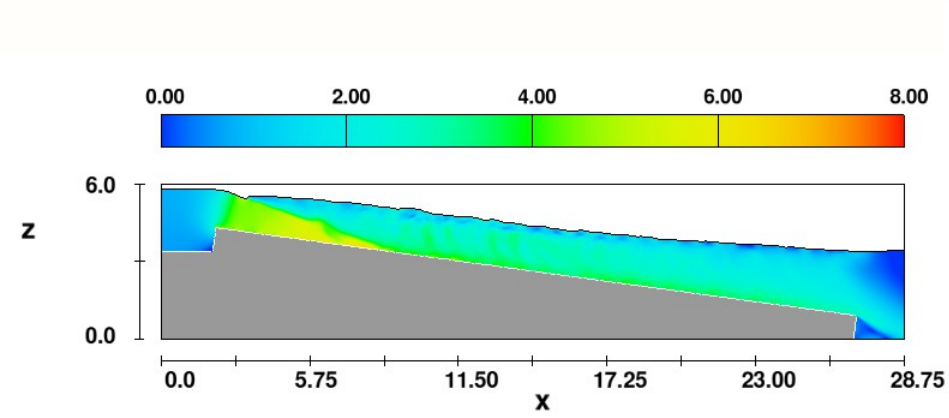
Model “A” Steeppass

Photo Credit: USFWS

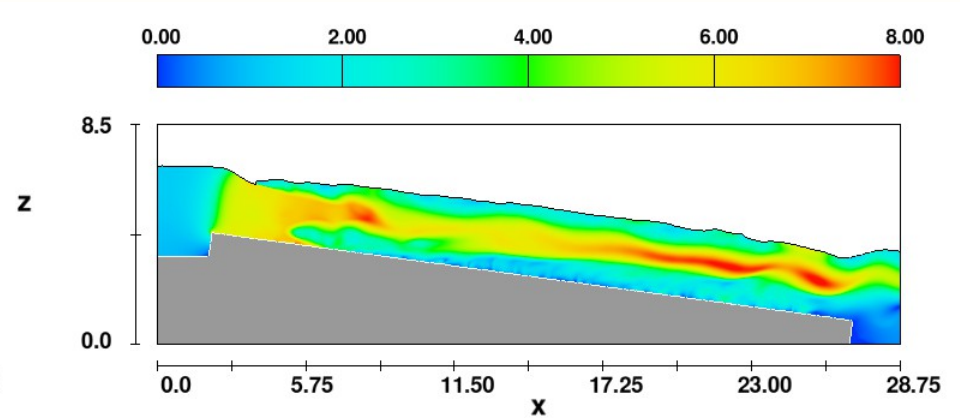
- designed by Ziemer in 1962 to pass salmonids
- baffle (Denil) type fishway
- prefabricated 27-inch high, 18-inch wide, 10 foot long sections
- highly portable and inexpensive
- suited to small streams and low head dams

CFD Results

velocity magnitude contours (ft/s)



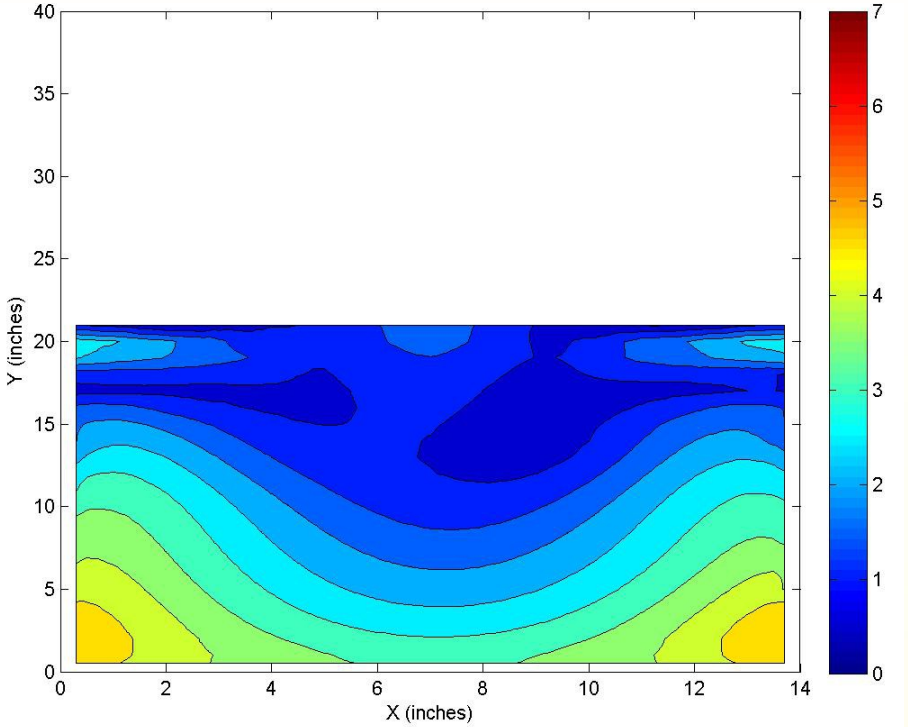
low head



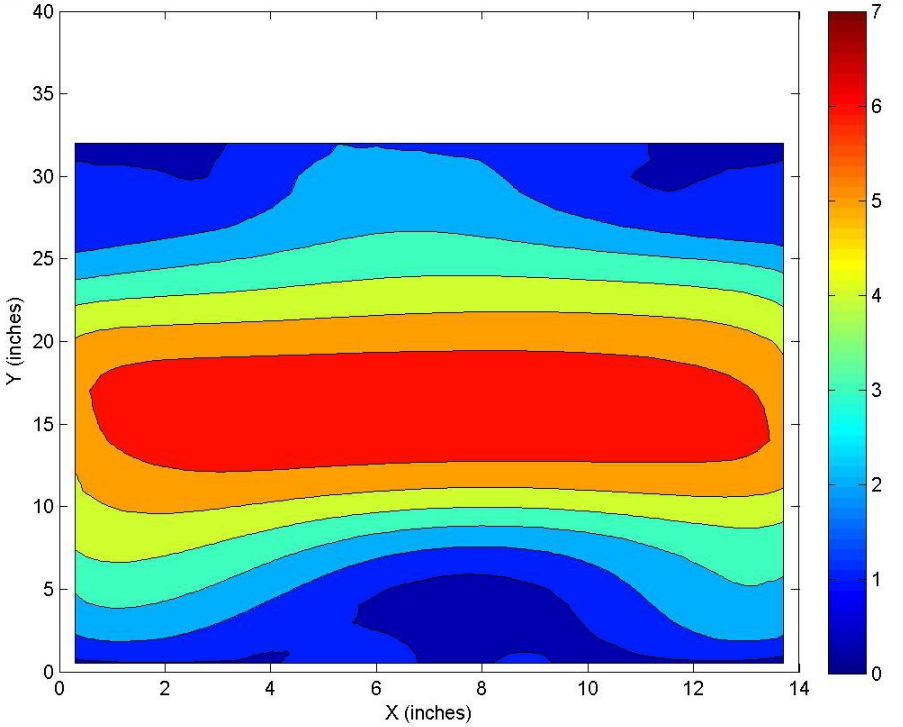
high head

CFD Results

velocity magnitude contours (ft/s)



low head



high head

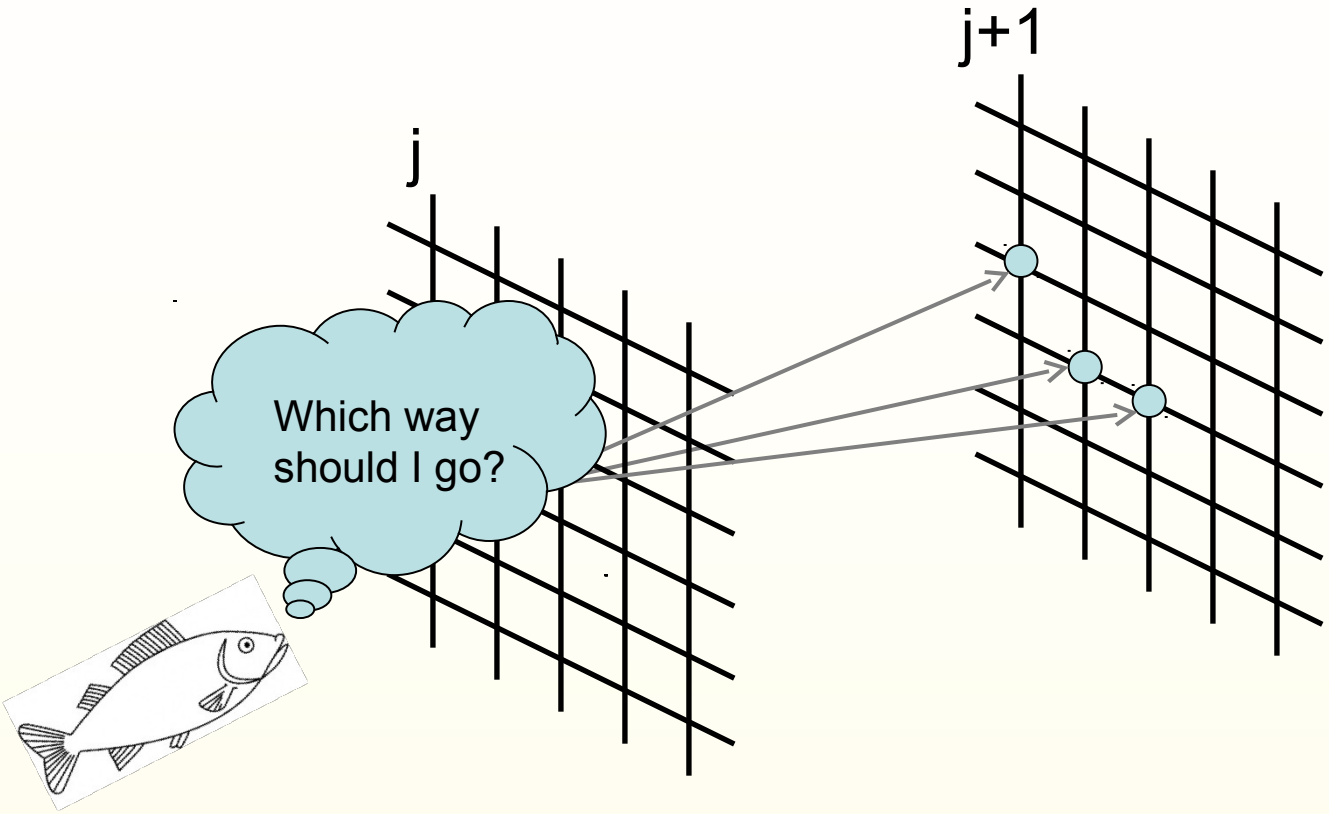
3D Passage Model - Overview

1. Extract velocity data from CFD model results
2. Choose fish path algorithm (straight, random, low velocity, etc.)
3. Use Monte Carlo simulation to randomize start point, fish size, and ground speed
4. Calculate *percent fatigue* for each cell as simulated fish advances
5. Calculate cumulative sum of percent fatigue
6. Fish fails to pass if sum of percent fatigue is greater than 100%
7. Repeat steps 3-6 to generate passage statistics

Inputs

- Fish length = 41.8 ± 3.49 cm^2
- Ground speed = 0.93 ± 0.53 BL/s^2
- Swim speed-fatigue curve coefficients[1]
- Start point on inlet grid
- Velocities from CFD model
- Water surface elevations from CFD model
- Constants (i.e. distances between cells)

Simulated Fish Path



Percent Fatigue[2]

- Assume constant “optimal” ground speed
- Each time interval consumes a portion of the time to failure (T), this is called ΔT

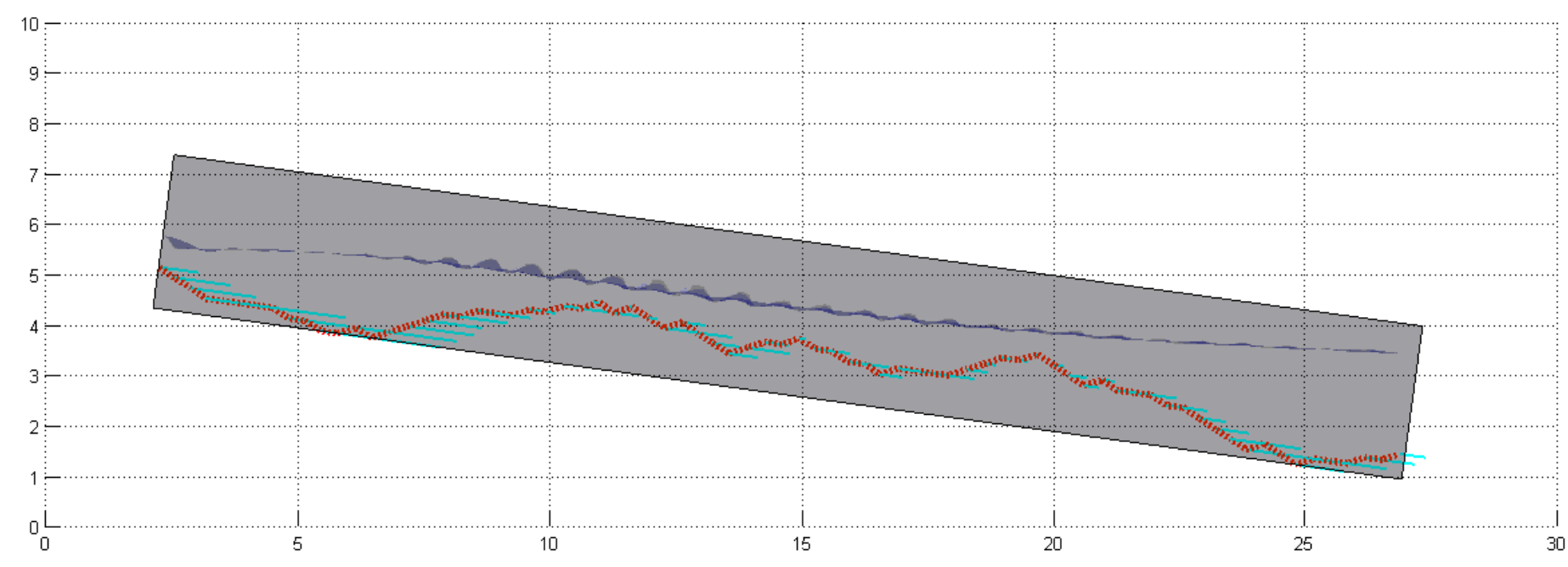
$$\Delta T = e^{-(a+bU_s)}dt$$

- U_s is fish speed which varies to maintain constant ground speed in variable velocity flow field
- Percent fatigue (F%) is the cumulative value of the ΔT’s

$$F\% = 100 \times \int_{\Delta t}^{T*} \Delta T$$

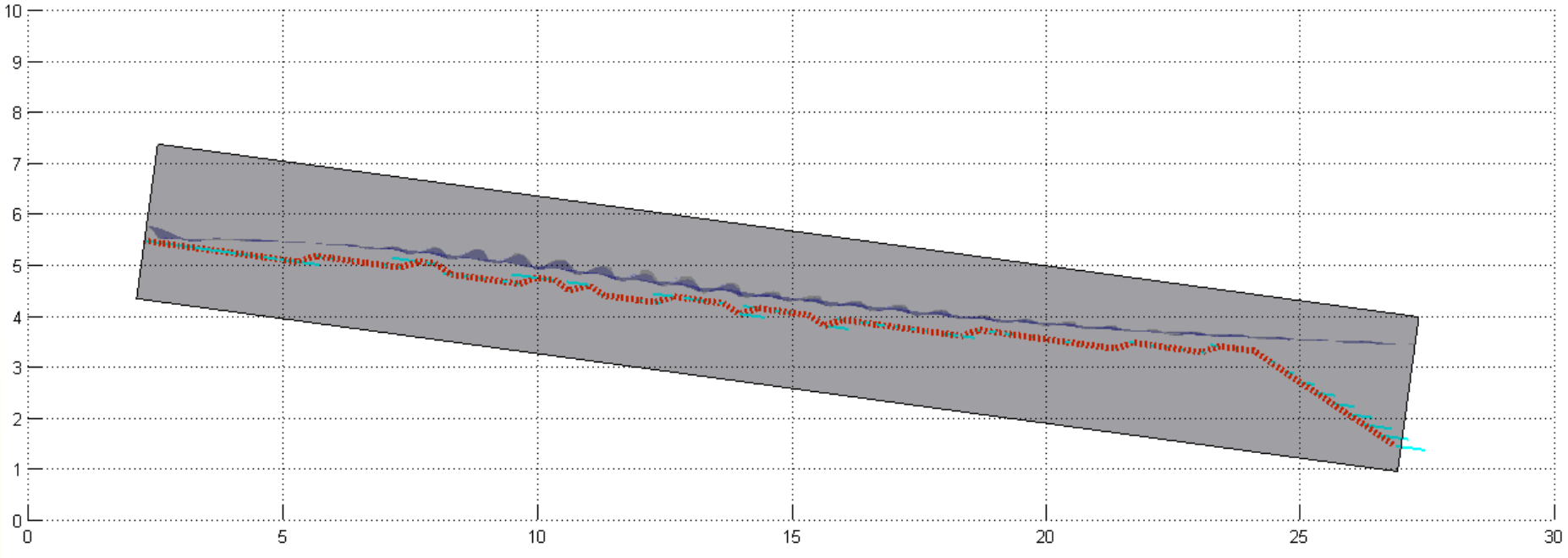
- Failure occurs when F% = 100%.

Simulated Fish Path



Random Path with Random Starting Point

Simulated Fish Path



Low Velocity Tendency Path with Random Starting Point

Results

1:8 Slope, Low Head

	Pass	Fail	Success Rate (%)	Average Energy (ft-lbf)	Average Fatigue (%)	Average Transit Time (s)	Average Power (hp)
Straight	4811	189	96.22	47.04	1.01	39.83	0.002
Random	4812	188	96.24	76.53	1.39	44.41	0.003
Low Velocity	4816	184	96.32	21.61	0.28	45.83	0.001
Low Velocity - Random	4816	184	96.32	27.21	0.36	46.27	0.001
High Velocity	4804	196	96.08	140.17	4.08	38.90	0.007
High Velocity - Random	4805	195	96.10	135.98	3.86	39.07	0.006

Results

1:8 Slope, High Head

	Pass	Fail	Success Rate (%)	Average Energy (ft-lbf)	Average Fatigue (%)	Average Transit Time (s)	Average Power (hp)
Straight	4787	213	95.74	119.64	5.36	34.83	0.006
Random	4791	209	95.82	191.77	6.74	38.47	0.009
Low Velocity	4815	185	96.30	29.92	0.48	44.59	0.001
Low Velocity - Random	4815	185	96.30	34.22	0.58	43.70	0.001
High Velocity	4711	289	94.22	279.23	18.11	30.62	0.017
High Velocity - Random	4711	289	94.22	292.27	17.87	31.16	0.017

Contrast with Field Study

	1:8 Low Passage (%)	1:8 Low Transit Time (sec)	1:8 High Passage (%)	1:8 High Transit Time (sec)
Passage Model	96	42	95	37
Field Data[3]	45	18	90	10

Conclusions

- The CFD model indicates a marked difference between HIGH and LOW velocity distributions
- Water velocity alone does not limit fish passage in this structure
- “Optimal” swim speed is not employed by American shad in the Steeppass

Acknowledgements

- Hydro Research Foundation
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- S.O. Conte Anadromous Fish Research Center, USGS
- US Fish and Wildlife Service, Region 5

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U.S. FISH & WILDLIFE SERVICE

References

[1]Castro-Santos, T. (2005). Optimal swim speeds for traversing velocity barriers: an analysis of volitional high-speed swimming behavior of migratory fishes. *Journal of Experimental Biology, 208*, 421-432.

[2]Castro-Santos, T. (2006). Modeling the effect of varying swim speeds on fish passage through velocity barriers. *Transactions of the American Fisheries Society, 135*, 1230-1237.

[3]Haro, A., Castro-Santos, T., & Noreika, J. (2004). *Evaluation of Passage Performance of a Deepened (Model A40) Alaska Steeppass Fishway for American Shad (Alosa sapidissima) and White Sucker(Catostomus commersoni).* U.S. Geological Survey.